UNCLASSIFIED

THIS PAGE IS UNCLASSIFIED

AD_____

GRANT NUMBER DAMD17-95-1-5070

TITLE: Pregnancy-Induced Changes in Body Fat, Physical Fitness
and Energy Requirements in Military and Civilian Women

PRINCIPAL INVESTIGATOR: Nancy F. Butte, Ph.D.

CONTRACTING ORGANIZATION: Baylor College of Medicine
                           Houston, TX   77030-3498

REPORT DATE: October 1996

TYPE OF REPORT: Annual

PREPARED FOR: Commander
              U.S. Army Medical Research and Materiel Command
              Fort Detrick, Frederick, Maryland   21702-5012

19971210 104

REPORT DOCUMENTATION PAGE

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE October 1996	3. REPORT TYPE AND DATES COVERED Annual (25 Sep 95 - 24 Sep 96)

4. TITLE AND SUBTITLE   Pregnancy-Induced Changes in Body Fat, Physical Fitness and Energy Requirements in Military and Civilian Women

5. FUNDING NUMBERS
DAMD17-95-1-5070

6. AUTHOR(S)
Nancy F. Butte, Ph.D.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Baylor College of Medicine
Houston, TX 77030-3498

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Medical Research and Materiel Command
Fort Detrick
Frederick, Maryland 21702-5012

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Distribution authorized to U.S. Government agencies only; Proprietary Information, Oct 96. Other requests for this document shall be referred to Comander, U.S. Army Medical Research and Materiel Command, ATTN: MCMR-RMI-S, Fort Detrick, Frederick, MD 21702-5012

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200*

This study addresses the impact of pregnancy-induced changes in body composition and physical fitness on postpartum return to duty readiness. We hypothesize that moderate levels of physical activity will maintain physical fitness and limit excess fat deposition during pregnancy without jeopardizing fetal growth if dietary intake is not restricted. Furthermore, moderate levels of physical activity will facilitate fat mobilization and conserve fat-free-mass (FFM) during postpartum weight loss.

Physical activity, weight, FFM and fat mass, fitness, strength, and iron status will be measured in 34 military reservists and 34 civilian women with low to normal pre-pregnancy BMI through a complete reproductive cycle (0, 8, 22, 36 wk gestation; 2, 6 and 24 wk postpartum). Physical activity will be quantified as the difference between total energy expenditure and basal metabolic rate measured by the doubly-labeled water method and room respiration calorimetry. Body volume (hydrodensitometry), total body water ($^2H/^{18}O$ dilution), potassium (^{40}K counting), nitrogen (prompt-gamma activation), and bone mineral (dual X-ray absorptiometry) will be used to calculate FFM and fat mass. Physical fitness will be determined by submaximal and maximal aerobic capacity tests. This report presents preliminary results on women prior to conception.

14. SUBJECT TERMS Defense Women's Health Research Program

15. NUMBER OF PAGES
42

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Limited

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

FOREWORD

Opinions, interpretations, conclusions and recommendations are those of the author and are not necessarily endorsed by the U.S. Army.

_____ Where copyrighted material is quoted, permission has been obtained to use such material.

_____ Where material from documents designated for limited distribution is quoted, permission has been obtained to use the material.

NFB X_ Citations of commercial organizations and trade names in this report do not constitute an official Department of Army endorsement or approval of the products or services of these organizations.

_____ In conducting research using animals, the investigator(s) adhered to the "Guide for the Care and Use of Laboratory Animals," prepared by the Committee on Care and use of Laboratory Animals of the Institute of Laboratory Resources, national Research Council (NIH Publication No. 86-23, Revised 1985).

NFB X_ For the protection of human subjects, the investigator(s) adhered to policies of applicable Federal Law 45 CFR 46.

_____ In conducting research utilizing recombinant DNA technology, the investigator(s) adhered to current guidelines promulgated by the National Institutes of Health.

_____ In the conduct of research utilizing recombinant DNA, the investigator(s) adhered to the NIH Guidelines for Research Involving Recombinant DNA Molecules.

_____ In the conduct of research involving hazardous organisms, the investigator(s) adhered to the CDC-NIH Guide for Biosafety in Microbiological and Biomedical Laboratories.

Nancy F. Butte _10-4-96_
PI - Signature   Date

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

5. INTRODUCTION

A. Subject, Hypothesis and Technical Objectives of the Research

The level of fatness associated with optimal physical fitness in women is less than the level of fatness associated with optimal fetal growth and survival. Women with low pre-pregnancy energy stores are at greater risk for fetal loss, premature delivery and intrauterine growth retardation. However, a low pre-pregnancy body mass index (BMI) can be compensated for by a greater pregnancy weight gain. In this study the effect of physical activity level on changes in physical fitness, weight, FFM, fat mass, energy expenditure will be evaluated through a complete reproductive cycle in sixty-eight women enrolled equally into 2 cells according to military or civilian status and stratified by pre-pregnancy BMI. Measurements will be done prior to pregnancy to establish pre-pregnancy nutritional status and physical fitness. During pregnancy measurements will be made at 8 wk (first trimester), 22 wk (second trimester), and 36 wk (third trimester). Postpartum measurements will be made at 2 wk to establish postpartum baseline body composition; at 6 wk when military and many civilian women return to work; and at 24 wk when military women must meet weight and physical fitness standards. We will investigate if military policies requiring women to return to weight and physical fitness standards by 6 mo postpartum are physiologically reasonable. The appropriateness of military body weight retention standards and the accuracy of the military equations used to predict body fat will be assessed in postpartum women.

Hypothesis

Moderate levels of *physical activity* will maintain *physical fitness* and limit *excess fat deposition* during pregnancy without jeopardizing fetal growth if dietary intake is not restricted, and facilitate *fat mobilization* and conserve *fat-free mass* during postpartum weight loss.

Technical Objectives

1. *The effect of physical activity level on pregnancy-induced and postpartum changes in weight, FFM and fat mass will be compared in military and civilian women with low to normal pre-pregnancy BMI.* Changes in FFM and fat mass will be computed from measurements of body volume, total body water, potassium, nitrogen and bone mineral through a complete reproductive cycle (pre-pregnancy-6 mo postpartum).

2. *The effect of physical activity level on pregnancy-induced and postpartum changes in physical fitness will be compared in military and civilian women.* Submaximal and maximal aerobic capacity will be measured through a complete reproductive cycle. The impact of body composition (specifically FFM, muscle mass and body fat), and iron status on physical performance will be assessed.

3. *The effect of physical activity level on the energy requirements of physically-active military and civilian adult women will be determined prior to pregnancy, during pregnancy and*

7

postpartum. Energy requirements will be estimated from rates of energy expenditure and energy deposition/mobilization.

B. Background of Previous Work

Military weight and body fat standards

The rationale for weight and body fat standards for accession and retention in the military as stated in Army regulation 600-9 (1) is "to insure that all personnel are able to meet the physical demands of their duties under combat conditions and present a trim military appearance at all times". Although similar, weight and body fat standards differ somewhat among the military services. If an individual exceeds the acceptable weight for height standard, body fat is assessed using anthropometric measures. The Army uses height, weight, and circumferences of neck, forearm, wrist, and hips in women to calculate body fat (2). The Navy uses height, weight and circumferences of neck, waist and hips in women (3). The Marines use height, weight, flexed biceps, forearm, neck, waist and thigh circumferences for women (4). The Air Force uses height, weight and forearm circumference (5).

The weight and body fat standards for accession and retention differ for men and women. Between 1960 and 1983 the maximum weight limits for women were lowered by 15-20 pds (AR 40-501)(6). The tables for women are considerably more restrictive relative to the national population. The military standard levels for body fatness are lower in men than women, acknowledging the fact that women biologically have higher body fat.

Table 1. Body fat standards for women as a percent of body weight (7)				
Age	17-20y	21-27y	28-39y	>40y
Army	30%	32%	34%	36%
Navy	------------------------36% ------------------------------			
Air Force	----------------28%-----------------------34%-----------			

However, accession and retention weight criteria are stricter for women than men. For enrollment into the Army men may be 37% above the desirable weight based on the 1959 Metropolitan Life Insurance Tables, while women can be only 6% above. For retention in the Army men can be 14% above desirable weight, and women only 5% above. Consequently, 29% of women Army recruits are rejected in contrast to 3% of male recruits (8). Military weight standards for women are set at an upper BMI limit of 24. Therefore, military women enter pregnancy with a low to normal BMI.

Performance standards

For retention in the military, personnel are evaluated regularly not only for weight compliance, but also for aerobic fitness (7). Physical fitness tests for women consist of a 1.5-2-mile run, push-ups and sit-ups or curl-ups. Although the tasks of military women are increasingly diverse, the military contends that all individuals need to maintain a certain level of physical fitness to preserve the combat readiness of the services. If an individual fails to

meet the body fat or physical fitness standards, he/she is assigned a program of diet and exercise. Individuals who do not lose sufficient weight or body fat are discharged from the military.

Pregnancy-induced changes in body weight

In the Institute of Medicine (9) appointed a Subcommittee to review the effect of gestational weight gain on maternal and child health and to make recommendations for optimal weight gain during pregnancy. Gestational weight gains associated with optimal infant outcome were found to be a function of maternal pre-pregnancy BMI. Several epidemiologic studies demonstrated that the effect of a given weight gain is greatest in thin women and least in overweight women. Pre-pregnancy BMI is also a determinant of fetal growth above and beyond its effect on gestational weight gain. Women with low pre-pregnancy BMIs tend to have smaller infants than those of their heavier counterparts. Low gestational weight gain is associated with a higher risk of intrauterine growth retardation and subsequent poor somatic and neurobehavioral development. Increased perinatal mortality among infants born to women with low weight gain especially those with low pre-pregnancy weight for height was seen in the Collaborative Perinatal Project (10) and the 1980 National Fetal Mortality Survey (11).

The Subcommittee concluded that desirable gestational weight gains should be based on pre-pregnancy BMI and should include the mean weight gain for women delivering full-term infants with birth weights in the optimal range of 3 to 4 kg (9).

Table 2. Recommended ranges of gestational weight gain by pre-pregnancy BMI (9)	
Weight for height category	Recommended total gain (kg)
Low (BMI<19.8)	12.5-18.0
Normal (BMI=19.8-26.0)	11.5-16.0
High (BMI>26.0-29.0)	7.0-11.5

Although gestational weight gain is correlated with birth weight, which component(s) of gestational weight gain is(are) critical for optimal fetal growth is unknown. Fetal growth may be influenced more by specific changes in fat-free mass (FFM), fat or water than by total gestational weight gain. In a study of 56 Swedish women total weight gain (14.8 kg), but not fat mass accretion (4-5 kg), was positively correlated with birth weight (12). However, their estimates of fat mass based on skinfolds were relatively imprecise. In another study of 115 Scottish women the lack of correlation between maternal fat accretion, estimated from weight retention 2-3 wk postpartum, and birth weight was confirmed (13). These results should be interpreted cautiously, since fat accretion was not measured directly and only women with normal pre-pregnancy BMI (22.5) were studied. In women with low pre-pregnancy BMI fat accretion may be more critical to fetal growth. There may be a threshold for maternal fat gain below which fetal growth is compromised. Further studies on the composition of weight gain in women with low and normal BMI and its impact on pregnancy outcome are needed.

Pregnancy-induced changes in body composition

The amount of FFM and fat accreted at any given gestational weight gain is poorly defined. Theoretical estimations of protein and fat deposition in the maternal (uterus, breasts, blood, adipose tissue, extracellular fluid) and fetal (fetus, placenta, amniotic fluid) compartments have been calculated for a 12.5 kg weight gain (14). Total body water increases continuously through pregnancy, primarily in extracellular fluids; therefore, the hydration of FFM increases substantially through pregnancy (15). Protein accretion rates estimated by recent nitrogen balance studies agree with Hytten's theoretical values (16). Therefore, it seems unlikely that protein is stored in excess of the amounts accounted for by the fetus and maternal reproductive tissues. The suggestion that protein is stored in muscle early in pregnancy, based on urinary 3-methylhistidine excretion data (17), has been refuted by others who attributed the higher urinary excretion of 3-methylhistidine to decreased renal tubular reabsorption and higher skeletal muscle turnover (16). Our measurements of total body nitrogen and potassium retention in pregnancy will resolve the amount and partitioning of protein deposited.

During pregnancy fat is deposited primarily in the subcutaneous adipose of the lower and upper trunk, and thighs (18-20), however, the amount of fat deposited is uncertain. Because of the increased hydration of FFM during pregnancy, standard techniques used to estimate fat deposition are invalid during pregnancy. Corrections were not applied in earlier dilution studies (15,21), but were in a later study (22), in which the mean fat gain was 2.77 ± 3.23 kg. Based on underwater weighing corrected for changes in the density of FFM, fat mass accretion was 2.7 ± 2.2 kg (23). Based on combined measurements of TBW and TBK, mean fat gains were 1.87 ± 2.23 kg (24) and 5.8 ± 4.0 kg (25). Recent values of fat gain differ from Hytten's original estimate of 3.3 kg fat. Technical errors undoubtedly contribute to the high variability in fat gain, but gestational weight gain, which is positively correlated with fat gain, is also variable in healthy women (26). Because of wide variation, changes in body composition can only be estimated from serial measurements, preferably with pre-pregnancy baseline values.

Postpartum weight and body fat loss

Postpartum weight loss is influenced by total gestational weight gain, age, parity, pre-pregnancy BMI, and feeding mode (27). The 1988 National Maternal and Infant Survey indicated a strong positive association between gestational weight gain and postpartum weight retention 10 to 18 months postpartum (28). Excessive weight retention was more common in black women in every weight gain category. Greater weight losses were observed in women with lower pre-pregnancy weights (20). Lactation facilitates weight loss in most women. Lactating women averaged 0.7 kg/mo weight loss during the first 4-6 mo postpartum (29,30). This weight loss was compatible with successful lactation and was associated with a decrease in body fat from 28.0 to 26.3%. Acceleration of weight loss may compromise lactation performance. Short-term energy restriction (1591 kcal/d for 1 wk resulting in a weight loss of 1.18 kg/wk) was associated with a fall in subsequent milk output and infant weight gain (31).

Accelerated weight loss may result in an undesirable loss of muscle mass in postpartum women (32). Whenever body weight is reduced, both FFM and fat mass contribute to the weight loss. For any given change in weight, the ratio ΔFFM/ ΔWT is inversely related to initial

10

body fat. However, exercise-training has been shown to enhance FFM preservation during diet restriction. Moderate exercise training reduced the amount of body weight lost as FFM compared to dietary restriction alone (33). Exercise training also can induce a greater energy deficit and mobilization of fat. We therefore hypothesize that dietary restriction combined with moderate levels of physical activity may preserve FFM in postpartum women.

When pregnant women perform nonweight-bearing exercise such as stationary cycling, oxygen consumption (VO_2 ($l\cdot min^{-1}$)) is either unchanged or only slightly increased at any given submaximal work rate compared to nonpregnant women (34). During submaximal weight-bearing exercise (eg. walking, running, treadmill exercise) maternal VO_2 ($l\cdot min^{-1}$) is significantly increased approximately in proportion to maternal weight gain. VO_2 expressed in $ml\cdot kg^{-1}\cdot min^{-1}$ is similar to or slightly reduced during pregnancy compared to nonpregnant state at the same speed and grade of walking. Limited data indicate that maximal VO_2 ($l\cdot min^{-1}$) during cycle ergometry and treadmill exercise is not altered by pregnancy compared to the postpartum period (35,36). However, in the only study in which aerobic capacity was assessed prior to pregnancy, VO_{2max}($ml\cdot kg^{-1}\cdot min^{-1}$) during cycle ergometry was higher pre-pregnancy compared to 4 to 8 wk postpartum (37). The decrement in VO_{2max} was attributed to increased body weight and decreased physical activity through pregnancy and the postpartum period. Whether this deconditioning effect is an inevitable consequence of pregnancy or whether moderate exercise throughout pregnancy can ameliorate the decline in aerobic capacity is uncertain. The effect of pregnancy-induced changes in body composition on physical fitness has not been evaluated through a reproductive cycle.

Moderate exercise under the ACOG Guidelines (38) poses minimal risk to the mother and her fetus. Such exercise programs may maintain aerobic fitness and control gestational weight gain (34). Strenuous exercise, on the other hand, may result in inadequate weight gain and give rise to smaller (300-500 g less) infants.

Effect of iron status on work capacity and performance

Maximal aerobic capacity in linearly related to hemoglobin concentration in humans (39). In iron deficiency without anemia skeletal muscle function is impaired by a decrease in mitochondrial iron-dependent enzymes of the electron transport chain and cytochromes. Iron deficiency induces a greater dependence on anaerobic glucose utilization, with lactic acidemia as a consequence. These defects reduce endurance and submaximal work performance. This is of practical importance since most human work is performed at submaximal levels (40% of VO_{2max}). In iron-deficient women without overt anemia total O_2 uptake and total energy expenditure were decreased, and post-exercise lactate concentration was increased in response to a progressive, graded aerobic capacity test on a cycle ergometer (40). Peak oxygen consumption was not impaired.

Postpartum women are "at risk" for iron deficiency or anemia. Iron losses during pregnancy include loss to the fetus and placenta, blood loss at delivery, and basal losses totalling approx. 840 mg (9). Blood loss during a cesarean delivery is almost twice that of a vaginal delivery. While we do not expect to find overt anemia in pregnant military women under medical surveillance, marginal iron deficiency may be present.

11

Pregnancy-induced changes in energy requirements

The energy requirement of pregnancy is a topic of considerable uncertainty as reflected in the lack of consensus in international recommendations: +1.20 MJ/d for all trimesters (41); +1.25 MJ/d for the last 2 trimesters (42); +0.80 MJ/d for the third trimester (43).

The energy requirement of pregnancy entails the energy deposited in maternal and fetal tissues and their associated increase in energy expenditure. Basal metabolic rate (BMR) steadily rises through pregnancy, due primarily to the products of conception and to a lesser extent to increased maternal cardiac and respiratory work. By late pregnancy VO_2 is 16-32% above nonpregnant values. Serial measurements of BMR through pregnancy indicate considerable interindividual variation in metabolic response (22,25,44,45), which was correlated to pre-pregnancy fatness, weight gain and fat gain (22). BMR actually declined in the first trimester in some women, suggesting increased metabolic efficiency. The lean women tended to be energy-sparing and the fatter women energy-profligate.

Total energy expenditure (TEE) using room calorimetry (46,47) and the doubly-labeled water method (22,48) has been measured longitudinally in only a few pregnant women. Near term TEE increased 1.5-2 MJ/d. Although changes in BMR accounted for most the increment in TEE, the level of physical activity contributed significantly to the variability in TEE.

The energy requirement of pregnancy will depend on the woman's gestational weight gain and the level of physical activity maintained throughout pregnancy. If a moderate level of physical activity and therefore physical fitness are maintained, it is of paramount importance that dietary intake is sufficient to meet maternal and fetal needs. In women with low pre-pregnancy BMI, if dietary intake is not sufficient to replenish maternal stores, fetal growth will be suboptimal. However, recommendations for dietary intake cannot be made, since the energy requirements of physically active pregnant women with low to normal pre-pregnancy BMI have not been quantified.

Nutritional implications for military women during reproduction

The nutritional problems of military women are similar to physically active civilian women participating in recreational sports. Inadequate intakes of iron and calcium place these weight-conscientious women at risk for anemia and osteoporosis (49). Friedl (50) reported that 36.6% of West Point cadets were at risk of developing iron deficiency. Inadequate iron nutriture may impact physical performance through its effect on O_2 transport and oxidative metabolism (39). The nutritional status of military women may be further jeopardized by the need to meet military body weight and fat standards.

Because pregnant military women are required to meet weight and physical fitness standards by 6 mo postpartum, they may restrain food intake and possibly jeopardize fetal growth. Postpartum military women may seriously restrict food intake to accelerate weight loss resulting in loss of fat and FFM, and possibly compromising milk production, if breast-feeding. Military women enter pregnancy with low to normal BMIs, since the military retention weight standards are equivalent to a BMI of 24. We calculated desirable gestational weight gains for optimal infant outcome and postpartum weight loss for women with low and normal pre-pregnancy BMIs (Table 3) based on the IOM recommendations for weight gain; an immediate

12

weight loss associated with the baby, placenta and amniotic fluid of 4.85 kg (14); diuresis resulting in an additional 3.0 kg loss by da 15 postpartum; further weight loss at an average rate of 0.7 kg/mo.

Table 3. Expected gestational weight gain and postpartum weight retention in military women		
	Low BMI	Normal BMI
Weight gain (kg)	12.5-18.0	11.5-16.0
Weight retention day 1 postpartum (kg)	7.6-13.1	6.6-11.2
Weight retention day 15 postpartum (kg)	4.6-10.1	3.6-8.2
Weight retention day 42 postpartum (kg)	3.6-9.1	2.7-7.2
Weight retention day 180 postpartum (kg)	0.4-5.9	0.6-4.0

If military women gain at the recommended levels and lose at a reasonable rate postpartum, they will return to active duty at da 42 postpartum with significant excess weight. At 6 mo when military women are expected to meet weight standards, many women will be 0.5-6.0 kg above their pre-pregnancy weight. In order the achieve the weight standards by 6 mo, military women must restrict dietary intake to accelerate weight loss.

The level of physical activity maintained by pregnant military women is uncertain. Although military "pregnancy profiles" exempt women from jobs requiring heavy physical work and eliminates physical fitness testing, these physically-fit women may voluntarily continue to exercise. Or they may become relatively inactive and physical fitness may decline due to deconditioning. Upon returning to work at 6 wk postpartum, military women are expected to perform at their pre-pregnancy work capacity. Whether pre-pregnancy physical fitness has been regained by 6 wk postpartum is uncertain. In only one study was aerobic capacity assess prior to pregnancy and 4-8 wk postpartum; a decline in aerobic capacity was observed postpartum and attributed to weight gain and decreased physical activity during pregnancy (37). Whether this detraining effect is inevitable during pregnancy or whether exercising throughout pregnancy ameliorates the decline is unknown.

Application of the body fat equations to postpartum women is questionable. Although the prediction equations for body fat have been cross-validated for men and women, they have not been evaluated for postpartum women (3). The Army and Navy equations may overestimate total body fat since these equations use hip circumference, a site of predominate fat deposition in pregnant women. The Air Force equation may underestimate total body fat since it uses forearm circumference which changes little during pregnancy.

Information relevant to the Military Recommended Dietary Allowances (51) for energy intakes of active duty and reserve military women will be provided by this study. Energy requirements of physically active women will be defined prior to, during and after pregnancy which may assist in the design of feeding strategies and food rations for military women.

13

6. Methods

Study Design

The effect of physical activity level on changes in physical fitness, weight, FFM, fat mass, and energy expenditure will be evaluated through a complete reproductive cycle in sixty-eight women. Women will be studied prior to conception, at each trimester, and at 2, 6 and 24 wk postpartum.

Table 4. Study design

	Pregnancy				Postpartum		
Study variables	0	8wk	22wk	36wk	2wk	6wk	24wk
Anthropometry	x	x	x	x	x	x	x
Hydrodensitometry	x	x	x	x	x		x
TBK	x	x	x	x	x		x
DEXA	x				x	x	x
TBN	x				x		x
TBW		x			x		
TEE/TBW	x		x	x			x
24-h calorimetry	x	x	x	x			x
Physical fitness	x	x	x	x		x	x
Iron status	x	x	x	x		x	x

Subjects

Sixty-eight women will be enrolled equally into 2 cells according to military or civilian status and stratified by pre-pregnancy BMI. An upper BMI limit of 24.0 was designated in accordance with military weight standards. However, we are enrolling women with BMI$\leq$26, to better match the military reserve population. Subjects will be healthy, physically-active, nonsmoking, ages 18-39 years, parity not greater than 4, no chronic medications or alcohol/drug abuse. Health history should be unremarkable (i.e., normotensive, glucose tolerant, nonanemic and euthyroid).

Methodology

Anthropometry. Maternal body weight to the nearest 0.1 kg will be measured with a digital balance (Scale-Tronix, Dallas TX). Height to the nearest 1 mm will be measured with a stadiometer (Holtain, Ltd, Crymmych, Pembs, UK). The circumferences of the head, chest, upper arm, forearm, wrist, neck, abdomen, thigh, and calf will be measured to the nearest 1 mm in duplicate with a metal tape. These sites include those currently used in military equations to predict body fat. Skinfold thicknesses will be measured to the nearest 0.5 mm in duplicate with a Lange skinfold caliper (Cambridge Scientific Industries, Cambridge, MD) at the following sites: triceps, biceps, subscapular, thigh, and suprailiac.

14

The U.S. Army, Navy and Air Force equations used to predict the body fat of women will be compared against other body composition models.

Table 5. Fat mass prediction equations for the U.S. Army, Navy, and Air Force servicewomen(7)

U.S. Army
$$FM(\%) = 105.3 \times \log_{10}(\text{weight}) - 0.20 \times \text{waist} - 0.533 \times \text{neck} - 1.574 \times \text{forearm} + 0.173 \times \text{hip} - 0.515 \times \text{height} - 35.6$$

U.S. Navy
$$\text{Density} = -0.35 \times \log_{10}(\text{abdomen I} + \text{hip} - \text{neck}) + 0.221 \times \log_{10}(\text{height}) + 1.296$$
$$FM(\%) = 100 \times [(4.95/\text{density}) - 4.5]$$

U.S. Air Force
$$FFM(\text{kg}) = 1.619 \times \text{forearm} + 0.311 \times \text{height} - 47.76$$
$$FM(\%) = 100 \times (\text{weight} - \text{FFM})/\text{weight}$$

Weight is in kg; height and body circumferences are in cm.
Note: As of 1996 the Air Force adopted the Navy equations for prediction of fat mass.

Hydrodensitometry. An underwater weighing system utilizing "force cube" transducers (Precision Biomedical Systems, Inc., State College, PA) will be used for body density measurements (52). Each subject will be requested to urinate, defecate, shampoo, shower, change to a swimming suit, and then submerge herself and exhale maximally while her body weight in the water is being measured. Residual lung volume will be measured using the simplified nitrogen washout method (53). Body density will be calculated from body weights in and out of the water and residual lung volume.

Total Body Potassium (TBK). Total body ^{40}K content of each subject will be measured using the CNRC low-background whole-body counter. The CNRC counting system consists of a total of 30 NaI(T1) detectors (each 10 cm x 10 cm x 45 cm) for a total detection volume of 135,000 cc. The detectors are arranged into two arrays positioned above and below the bed with the subject in a supine position. The subject will lie supine for 15 minutes while the body's natural gamma ray signal is recorded. The gamma signal is directly proportional to the amount of potassium in the body. The precision of the ^{40}K counting is <1% in adults.

Dual Energy X-ray Absorptiometry (DEXA). Composition of the total body and major subregions will be measured using a Hologic QDR 2000W system (Hologic, Inc., Madison, WI). Subregions include the head, thoracic spine, ribs, lumbar spine, pelvis, arms, and legs. The whole body scan takes approximately 15 minutes with the subject lying supine. The low dose (<0.01 mSv) has allowed for IRB approval of research measurements in healthy individuals. Over a 2 y period the average precision for bone mineral density using the spine phantom was ±0.6%.

Total Body Nitrogen (TBN). Prompt-Gamma Activation Analysis will be used to measure TBN. The subject is placed in a very weak neutron beam: neutrons interact with body tissues and generate a gamma signal that can be detected external to the body. This technique induces

15

activities of interest that are very short-lived (less than 1 μsec) which requires the detection system to be included in the irradiator assembly. Two shielded, collimated AmBe sources provide a bilateral beam through which the subject is scanned. Four large volume NaI(T1) detectors with custom designed neutron/gamma shielding are positioned at 90° to both the bed and sources. The scan time is about 15 min; the dose is less than 0.3 mSv (comparable to a chest x-ray). In pigs, the *in vivo* precision was determined to be 3.5% for body nitrogen.

Muscle and Nonmuscle Mass. In the nonpregnant women TBK and TBN will be used to estimate the relative amounts of protein in muscle and nonmuscle components of the body and the mass of each component (54). The principle underlying this approach is that the K/N ratio for muscle is higher than that of nonmuscle tissues (3.03 vs 1.33 meq/g). Assuming the values of 30 g N/kg and 91 meq K/kg muscle, and 36 g N/kg and 48 meq K/kg nonmuscle, total muscle mass is equal to (K-1.33N)/51.0 and total nonmuscle mass is equal to (3.03 N-K)/61.2.

Body Composition Models. The Fuller (55) four-compartment model that combines total body water (TBW), body density and DEXA measurements will be used to compute fat-free mass (FFM) and fat mass (FM). A constant ratio of bone mineral to non-osseous mineral (0.8191:0.1809) is assumed. The equation used is: FM(kg) = 2.747 body volume - 0.710 TBW + 1.460 total body bone ash - 2.050 weight. Gestational values for total body bone ash will be linearly interpolated from pre-pregnancy and day 15 postpartum measurements. Regional fat deposition during pregnancy and mobilization postpartum will be studied through all reproductive phases using anthropometry and DEXA. Subregions described by DEXA include the head, thoracic spine, ribs, lumbar spine, pelvis, arms, and legs.

Total Body Water (TBW). After collection of baseline saliva samples, 40 mg ^2H_2O/kg in the form of water will be administered orally at 8 and 36 wk of gestation, and 2 and 24 wk postpartum. The ^2H abundance in saliva samples will be measured by gas-isotope-ratio mass spectrometry. TBW will be calculated from the elevation of ^2H abundance in the 4-h and 6-h postdose samples. TBW will be determined from $^2H_2^{18}O$ dilution prior to pregnancy and at 22 wk gestation, and at 24 wk postpartum (see TEE).

Total Energy Expenditure. Total energy expenditure (TEE) over a 14-day period will be calculated from the fractional turnover rates of ^2H and ^{18}O following oral ingestion of 100 mg/kg ^2H_2O and 125 mg ^{18}O as water (56). Isotope dilution spaces will be used to compute TBW. Baseline saliva samples will be collected from each subject. Subsequently, one daily saliva sample will be collected by each subject at home for the next 14 days. The ^2H and ^{18}O abundances of the saliva samples will be measured by gas-isotope-ratio mass spectrometry. Carbon dioxide production (VCO_2) will be calculated from the dilution spaces and fractional turnover rates of ^2H and ^{18}O using the multipoint slope-intercept method of calculation. Fractionated insensible water losses will be calculated from ventilatory volume and body surface area, both expressed as functions of CO_2 production. Respiratory quotient will be computed from the food quotient based on dietary records (57). TEE will be calculated using the Weir equation (58).

Room Respiration Calorimetry. Oxygen consumption (VO_2) and VCO_2 of mothers will be measured and monitored continuously in a room-sized indirect calorimeter for 24-h (59). Energy expenditure will be calculated from VO_2 and VCO_2. Performance tests with N_2 and CO_2 infusions demonstrated that the accuracy of individual measurements of VO_2 and VCO_2 were 3%. System

16

response to a step change exceeded 90% in 4 min. Sleeping metabolic rate (SMR), and basal metabolic rate (BMR) will be extracted from specific time periods. BMR will be measured for 40 minutes while the subject lies quietly 30 min after awaking and voiding. Fat and carbohydrate net utilization will be computed using 24-h excretion rates of urinary nitrogen according to Livesey (60).

The heart rate of the subject will be monitored and recorded continuously by telemetry (Dynascope 3300 Telemetry System, Fukuda Denshi America). During the 24-h period in the calorimeter, subjects will be asked to adhere to a schedule of feeding, sleeping and exercise times. Energy intake will be controlled according to body weight. Subjects will walk twice for 10 minute each at 2.5 and 3.5 mph, no grade, on a treadmill.

Physical Activity. Physical activity level, our major independent variable, will be determined by combining the doubly-labeled water method with respiration calorimetry. Physical activity level will be quantified in terms of MJ/d as the difference between TEE and BMR. Physical activity level will be described qualitatively using the Minnesota Leisure Time Activity Scale (61) combined with the Health Insurance Plan (HIP) Questionnaire for assessment of occupational activity (62).

Physical Fitness. Maximal VO_2 will be measured in nonpregnant women who will undergo a stepwise increase in exercise intensity until volitional fatigue is achieved (3-Corval 400, LODE B.V., Groningen, Holland and 2-Combi Cycle EX80, Combi, Co., LTD. Tokyo). Subjects will cycle for 4 min at 50 watts for steady state determination of VO_2, and then the workload will be increased by 25 watts every minute. VO_2 consumption will be measured continuously via the open circuit technique with a metabolic cart (SensorMedics 2900; Yorba Linda, CA). Heart rate and blood pressure will be monitored. Steady-state heart rate and VO_2 values will be used to estimate VO_{2max}.

Submaximal VO_2 also will be measured in the room respiration calorimeter, unimpeded by a mouthpiece apparatus. In the morning and afternoon women will walk for 20 minute at 2.5 mph, no grade, on a treadmill (905E, Precor, Bothell, WA); heart rate will not be allowed to exceed 140 bpm in pregnant women.

Strength. Prior to the 1 RM strength assessments, the subject will practice using the equipment to become familiar with the proper exercise techniques and to prevent injuries. The upper and lower body 1 RM strength tests will be done utilizing the Cybex Smith Press and the Cybex Latissimus Pulldown (upper body), and the Cybex Modular Leg Press and the Cybex Leg Extension (lower body). The 1 RM is defined as the maximum amount of weight that can be lifted successfully one time only. Starting with a weight used in the practice session, the subjects will attempt lifts with gradually increasing weight (10% at first, decreasing to 5 and 2.5% as difficulty becomes evident). Successive attempts will be made with a 90-s rest between attempts until failure occurs. These measurements will be done at the Texas Children's Hospital Wellness Center within the Department of Pediatrics.

Infant Outcome. Birthweight, length and gestational age will be recorded from medical records.

Biochemical Analysis. A 12-h fasting blood sample will be obtained for the following analyses. A Complete Blood Count and Differential including hemoglobin and hematocrit will be performed by Smith Kline Beecham Clinical Laboratories. Standard techniques of flow cytometry, automated

cytochemistry and microscopy are used. Serum iron and total iron binding capacity will be measured using atomic absorption spectrophotometry (Perkin-Elmer Corp., Norwalk, Conn). Serum ferritin will be determined by ^{125}I-radioimmunoassay (Diagnostic Products Corp., CA). To correct calorimetry data, 24-h urinary nitrogen will be determined by the Kjeldahl method (Tecator, Högänäs, Sweden).

Statistical Analysis. Analysis of variance and covariance with repeated measures will be used to test our hypothesis. The grouping factors will be status (military or civilian) and pre-pregnancy BMI stratification criteria (<19.8 or 19.9-24.0). The within factors will be pregnancy status (antepartum or postpartum), and time (levels= 0, 8, 22, 36 wk gestation; 2, 6 and 24 wk postpartum). The major independent variable to be tested is physical activity level. The dependent variables to be analyzed under this model will be weight, FFM, fat mass, energy expenditure, and physical fitness. Covariates to be included in the model are age, parity, iron status and infant feeding mode. Pre-pregnancy BMI will be treated also as a continuous variable in a separate analysis. We will also use multiple regression analysis to investigate relationships between the various dependent variables, and test if these relationships differ between military and civilian women. Statistical analyses will be performed using BMDP (63) and Minitab (64) statistical packages. Microsoft ACCESS will be used for data management.

7. RESULTS and DISCUSSION

Subject Enrollment:

A total of 220 women responded to recruiting initiatives of whom 108 passed the preliminary screening criteria and were invited to tour the CNRC facility with their spouse (or partner) and to meet the investigators.

Thirty-four women have been enrolled into the "Fit for Life" study and 26 women have completed one or more study periods. Of the 34 participants, 6 are military reservists and 28 are civilians. The ethnic breakdown consists of 2 Hispanic, 10 African-American, and 22 Caucasian women. Prior to pregnancy, 6 participants are in the low BMI group ($\leq$19.8).

Subject Recruitment for "FIT for Life" Study:

Recruitment of civilians was initiated before recruitment of military personnel. Several preliminary steps were required before recruiting could begin at military installations including final grant approval, Military Institutional Review Boards for Research in Human Subjects approval, and establishment of lines of communication with U.S. Army, Air Force, and Navy Reserve units in the Greater Houston Area. Final grant approval was received from the Department of Defense on January 2, 1996. Subsequently, working relationships were established with contacts at 13 military installations, and recruitment efforts were implemented as detailed in Table 6.

Some techniques used for civilian recruitment were not readily adapted to the military or were less successful in this population. Strategies used for recruiting civilians include: paid advertisements in a local magazine, Health and Fitness; announcements in a wide variety of local newsletters; direct mailing to former study volunteers, area physicians, and other members of our

18

established community-based referral system; fliers and posters placed in physician's offices, gymnasiums, local universities and the Texas Medical Center; and booths and presentations at local health fairs or special events.

Direct mailings to all eligible women in the Air Force Reserves and Air National Guard (200), and Naval Reserves (126) living in the Greater Houston Area were completed by February, 1996. A similar mailing to local women in the Army Reserve and Army National Guard will be initiated, as soon as the necessary clearance and the mailing list are received from the Army Reserve Personnel Center in St. Louis, MO. While advertising in a local fitness magazine is our most successful strategy for recruiting civilians, no comparable publication could be identified, which targeted local military reservists. Advertisements in the Army, Air Force, and Navy Times were deemed inappropriate, because of their national and international distribution. Announcements have been made in Army and Air National Guard newsletters and e-mail bulletins; and Army Reserve family support personnel have distributed fliers. Since January, 1996, fliers announcing the study have been distributed to military reservists who attended weekend drills in the Houston area, and periodically, announcements of the study have been made by commanders prior to drill exercises.

Initial recruitment of military women was slower than anticipated. Although this may have resulted in part from the large deployment of Houston area reservists to Bosnia during the first half of 1996, recruitment strategies were re-evaluated in April. Analysis of responses to early recruiting initiatives confirmed that the majority of pregnancies among military women are unplanned, and that approximately 1/3 of female reservists exceed the mandated upper limit of 24 for BMI at any given time. Since the postpartum period is of primary interest in assessing duty readiness in military women, we requested and received permission (4/96) to enroll military personnel after the onset of pregnancy. Moreover, in order to better match the military population, we extended the upper BMI cut-off for enrollment of civilian women to 26 and eliminated BMI as an enrollment criteria for military women. The importance of these changes in enrollment criteria is illustrated by the fact that 5 of the 6 military women now enrolled in the study were pregnant at the time of enrollment, and 3 reported a pre-pregnancy BMI greater than 24.

A new recruitment strategy intended to offer both continual visibility for the study and privacy for potential volunteers was devised in May, 1996. A large, laminated poster depicting an exercising women in early pregnancy was designed and produced by our graphic arts specialist. Posters with attached holders containing complimentary 3x5 cards were posted in all local military reserve installations. At the same time, recruitment was expanded to include reserve installations outside the Greater Houston Area in Pasadena, Beaumont-Port Arthur, Bryan-College Station, La Port, La Marque, and Ellington Field. Reserve personnel have been exceptionally cooperative in identifying optimal locations for the recruiting posters, and the number of calls from reservists has escalated since the posters and card holders were installed. Accordingly, the rate of enrollment of military women has increased.

Table 6. Strategies for recruitment at military reserve installations in the vicinity of Houston, Texas

Branch/ location/unit	Date of Initiation	Strategy
U.S. ARMY		
Army Reserves		
Houston		
1850 OST:	1/96	**Fliers**
4151st USAF school		**Newsletter announcements**
4005th USAH, sec 2	3/96	**Family support distribution**
75th Div	4/96	**Booth + discussion at drill weekends**
	6/96	**Posters + cards**
Houston		
6903 Perimeter Park Dr:	7/96	**Posters + cards + fliers**
AMSA-4 Maint		
348th TC Bn		
369th TC Det		
614th TC Det		
31st TC Det		
441st TC Co		
1st JAG Det		
7077 Perimeter Park Dr:		
340th CML Co		
327th CML Co		
430th ENG Plt		
450th CML Bn		
808th EN Co		
Pasadena	7/96	**Poster + cards + fliers**
301st MI Bn		
301st MI Bn A Co		
Bryan	7/96	**Newsletter announcements**
HQ - 420th EN Brig		**Posters + cards + fliers**
837th MI Det		
443rd MI Det		
Beaumont / Port Arthur	8/96	**Posters + cards + fliers**

U.S. ARMY (con't)

Army National Guard
Houston
HQ 536th	1/96	**Fliers**
136th, company C	2/96	**e-mail bulletins**
	7/96	**Posters + cards**

Ellington Field
Hq 1-149th Avn Regt	2/96	**Fliers**
	7/96	**Posters + cards**

La Marque	2/96	**Fliers**
536th, company C	7/96	**Posters + cards**

U.S. AIR FORCE

Air National Guard - Texas	12/95	**DIRECT MAILING**
Ellington Field	7/96	**Posters + cards + fliers**
147th Fighter Group		
La Port		
272nd EIS	7//96	**E-mail bulletin**
		Posters + cards + fliers
Beaumont		
273rd EIS	7//96	**Posters + cards + fliers**

U.S. NAVY

Naval Reserves	2/96	**DIRECT MAILING**
Houston	1/96	**Fliers**
1902 OST		**Announcements at drill**
Naval Reserve Readiness Center	6/96	**Posters + cards**
7509 SW Frwy (annex)		

Preliminary Data Presentation

   Data will be presented on the first 19 women enrolled into the "FIT for LIFE" study. Six of these subjects have conceived and their data during pregnancy are presented for illustrative purposes only. Needless to say, no conclusions on pregnancy-induced changes in body fat, physical fitness and energy requirements can be made at this early phase of the study.

Reproductive History

   The age of the women enrolled thus far ranges from 24 to 39 y. Reproductive history indicates normal menses, except in a few cases with prolonged oral contraceptive use. Presently, the women have one or no children.

Table 7. Reproductive history	
	N=19
Maternal age (y)	31.7 ± 4.4*
Menarche age (y)	13.0 ± 1.8
Menses interval (d)	29.0 ± 3.4
Menses duration (d)	4.4 ± 1.1
Gravidity	0.8 ± 0.8
Parity	0.3 ± 0.5

*Mean ± SD

Iron Status

Iron status will be assessed throughout the reproductive cycle, because of its potential effect on pregnancy outcome, work capacity, and physical fitness. Prior to pregnancy, there is no evidence of iron deficiency or anemia in these women, based on normal values for hemoglobin, hematocrit, serum iron and transferrin. Serum ferritin, an indicator of iron stores, also fell within the normal limits for all women.

Iron metabolism and erythrocyte indices are altered by the physiological changes of normal pregnancy. Serum iron decreases with increasing duration of pregnancy due to plasma volume expansion. Serum transferrin increases by ~2.4 fold due to estrogen-stimulated hepatic protein synthesis; iron saturation accordingly decreases. Serum ferritin decreases as iron stores are used for expansion of erythrocyte mass. Because of these changes in iron metabolism, it is difficult to distinguish anemia due to iron deficiency from dilutional anemia. To provide a more sensitive indicator of iron deficiency in pregnancy, we are evaluating an EIA assay for serum transferrin receptor (Ramco Laboratories Inc.). Serum ferritin and transferrin receptor will be monitored throughout the reproductive cycle to evaluate the impact of iron status on pregnancy outcome and postpartum recovery.

Table 8. Iron status			
	Pre-pregnancy n=19	8 wk pregnancy n=6	22 wk pregnancy n=4
Hemoglobin (g/dl)	13.7 ± 1.0*	13.0 ± 1.2	12.4 ± 0.8
Hematocrit (%)	40.5 ± 3.6	38.1 ± 3.7	35.7 ± 2.5
Serum iron (μg/dl)	103.3 ± 27.0	114.4 ± 14.4	95.3 ± 24.7
Iron binding capacity (μg/dl)	313.5 ± 52.2	310.4 ± 37.7	362.8 ± 42.3
Iron saturation (%)	33.2 ± 9.4	37.5 ± 7.0	26.3 ± 6.1
Ferritin (ng/ml)	55.6 ± 50.8	49.1 ± 24.8	24.3 ± 12.1
White blood cell count (WBC) ($\times 10^9$/L)	6.3 ± 1.9	8.6 ± 2.9	14.4 ± 3.9
Red blood cell count (RBC) ($\times 10^{12}$/L)	4.4 ± 0.4	4.1 ± 0.5	3.8 ± 0.3
Mean corpuscular volume (MCV) (fL)	92.0 ± 4.1	92.7 ± 4.2	93.5 ± 3.8
Mean corpuscular hemoglobin (MCH) (pg)	31.0 ± 1.5	31.8 ± 1.7	32.3 ± 1.4
Mean corpuscular hemoglobin concentration (MCHC) (%)	33.7 ± 0.8	34.3 ± 0.7	34.5 ± 0.7

*Mean±SD

Anthropometry

The anthropometric measurements reflect a wide array of body sizes. The mean BMI was 22.3 ± 2.5. Height ranges between 157 and 177 cm. Prior to conception weight varied between 50 and 82 kg. Anthropometric measurements will be used to monitor gestation weight gain/postpartum weight loss, and site-specific deposition/postpartum mobilization of subcutaneous body fat.

Table 9. Anthropometry				
		Pre-pregnancy n=19	8 wk pregnancy n=6	22 wk pregnancy n=4
Weight	kg	61.2 ± 9.7*	62.0 ± 11.4	63.6 ± 6.4
Height	m	1.65 ± 0.06	1.65 ± 0.06	1.58 ± 0.09
Body mass index (BMI)	kg/m^2	22.3 ± 2.5	22.8 ± 3.2	25.4 ± 2.8
Head circumference	cm	54.6 ± 1.3	54.4 ± 1.0	54.6 ± 1.3
Neck circumference	cm	31.6 ± 1.6	32.0 ± 2.3	31.6 ± 0.7
Chest circumference	cm	88.7 ± 5.9	92.2 ± 6.3	95.6 ± 6.5
Waist circumference	cm	70.6 ± 5.9	75.2 ± 5.3	84.2 ± 4.4
Hip circumference	cm	96.2 ± 6.8	96.3 ± 9.3	97.2 ± 6.9
Thigh circumference	cm	49.2 ± 3.6	49.1 ± 6.3	49.7 ± 3.1
Calf circumference	cm	36.0 ± 2.6	36.0 ± 2.4	36.0 ± 2.4
Wrist circumference	cm	14.6 ± 0.7	14.5 ± 1.0	14.4 ± 0.5
AF Forearm circumference	cm	23.7 ± 1.6	23.8 ± 2.2	23.8 ± 0.7
Army forearm circumference	cm	23.9 ± 1.7	24.0 ± 2.2	24.1 ± 0.7
Upper arm circumference	cm	27.6 ± 3.3	28.4 ± 4.4	28.8 ± 2.4
Triceps skinfold	mm	15.8 ± 7.7	21.0 ± 10.1	23.6 ± 10.5
Biceps skinfold	mm	6.4 ± 6.0	9.8 ± 9.7	10.3 ± 5.9
Subscapular skinfold	mm	14.4 ± 8.1	18.9 ± 10.2	25.0 ± 11.9
Suprailiac skinfold	mm	15.2 ± 9.1	23.0 ± 11.6	26.2 ± 10.2
Thigh skinfold	cm	26.1 ± 9.5	28.6 ± 14.1	33.7 ± 15.0
Sagittal diameter	cm	14.5 ± 1.2	**	**

*Mean ± SD
**Measurement not performed during pregnancy

UNPUBLISHED

Body Composition

Standard 2-component body composition models based on deuterium dilution, hydrodensitometry, or total body potassium, while applicable prior to conception, are invalidated during pregnancy due to the expansion of body fluid compartments. Further, postpartum normalization of FFM hydration has not been well characterized, and therefore, the validity of standard 2-component models is uncertain for an undetermined time period following delivery. To obtain more accurate estimates of FFM and FM in reproductive women, we have chosen the Fuller 4-component model, which minimizes assumptions regarding the hydration of FFM and the bone mineral content of dry FFM, by incorporating measurements of total body water, body density, and BMC (55). This model also provides more accurate body composition estimates in non-pregnant individuals. A comparison of FM estimated by the standard and multicomponent body composition models is presented in Table 10.

Table 10. Fat mass (FM) estimated by deuterium dilution, hydrodensitometry, total body potassium, DEXA, and skinfold thicknesses, and multi-component models				
		Pre-pregnancy n=19	8 wk pregnancy n=6	22 wk pregnancy n=4
Deuterium dilution				
Total body water (TBW)	kg	33.53 ± 4.91*	31.11 ± 1.11	**
FM	kg	15.60 ± 5.20	15.49 ± 5.84	**
Hydrodensitometry (HD)				
Body volume	l	59.12 ± 9.83	59.03 ± 12.35	62.07 ± 6.55
Body density	kg/l	1.04 ± 0.01	1.03 ± 0.01	1.03 ± 0.01
FM	kg	17.11 ± 6.03	18.75 ± 7.72	20.17 ± 4.52
Total body potassium (TBK)				
FM	kg	15.90 ± 7.60	20.03 ± 8.94	21.10 ± 5.60
Dual energy x-ray absorptiometry (DEXA)				
FM	kg	16.64 ± 7.17	***	***
Skinfold thicknesses (Durnin & Womersley)				
Body density	kg/l	1.04 ± 0.01	1.03 ± 0.02	1.02 ± 0.01
FM	kg	16.83 ± 6.58	20.13 ± 8.30	21.87 ± 5.50
Multi-component models				
FM-Siri (TBW, HD)	kg	16.41 ± 5.52	15.80 ± 5.21	**
FM-Fuller (TBW, HD, DEXA)	kg	17.04 ± 5.63	16.48 ± 5.95	**

*Mean ±SD
** Data not yet available from laboratory
*** Measurement not performed during pregnancy
Abbreviations: TBW, total body water; HD, hydrodensitometry; TBK, total body potassium; DEXA, dual energy x-ray absorptiometry; SF, skinfold thicknesses.

FM and % body fat at the pre-pregnancy time point estimated by military equations and by standard and multi-component models are listed in Table 11. Mean pre-pregnancy body fat was 17.0 ± 5.6 kg, or 27.1 ± 5.0% by the Fuller 4-component model. Fat mass predicted from military equations depends on different anthropometric sites. The Army equation uses the waist and hip circumferences and builds in BMI ie. weight and height measurements; the Navy equation predicts density from abdomen, hip and height; the Air Force equation derives FFM from forearm and height. All subjects would have been eligible for enrollment into each branch of the Armed Services, according to the currently used Army and Navy equations. Two subjects would not have qualified for enrollment into the Air Force based on the Fuller 4-component estimate of body fat.

FM derived from the Fuller 4-component model and military equations were highly correlated (r^2 = 0.85-0.86). Percent FM derived from the Fuller 4-component model and military equations also were significantly correlated, but to a lesser extent (r^2 = 0.52-0.57) (Figures 1-3). The Air Force equation significantly overestimated both the mean FM and % FM in this group of women, and the Army and Navy equations tended to underestimate mean FM and % FM.

Bland-Altman plots illustrate the differences in % FM derived from the Fuller 4-component model and military equations (Figures 4-6). Preliminary analysis suggests poor agreement between methods for some individuals, however, the number of subjects examined to date is not sufficient to reliably characterize the extent of intermethod differences. With our full data-set of preconceptional women we will be able to evaluate the accuracy of the military FM prediction equations. We will also evaluate these predictive equations for use in postpartum women. Further, the effect of gestational weight gain and fat accretion on the ability to return to body fat standards in the 6 months following delivery will be assessed.

Table 11. Body fat mass (FM) predicted from military equations and body composition models at the pre-pregnancy study interval		
	Fat mass (kg) n=19	Fat mass (%WT) n=19
FM-Army equation	16.16 ± 4.55*	26.06 ± 3.81
FM-Navy equation	16.02 ± 5.47	25.64 ± 4.66
FM-Air Force equation	19.08 ± 6.25	30.55 ± 5.40
FM (TBW)	15.60 ± 5.20	24.94 ± 5.13
FM (HD)	17.11 ± 6.03	27.43± 5.95
FM (TBK)	15.90 ± 7.60	25.21 ± 8.71
FM (DEXA)	16.64 ± 7.17	26.35 ± 7.40
FM (SF)	16.83 ± 6.58	26.84 ± 6.56
FM-Siri (TBW, HD)	16.41 ± 5.52	26.17 ± 5.00
FM-Fuller (TBW, HD, DEXA)	17.04 ± 5.63	27.11 ± 5.00

*Mean ± SD

Figure 1.

Figure 2.

Figure 3.

Figure 4.

Figure 5.

Figure 6.

27

UNPUBLISHED
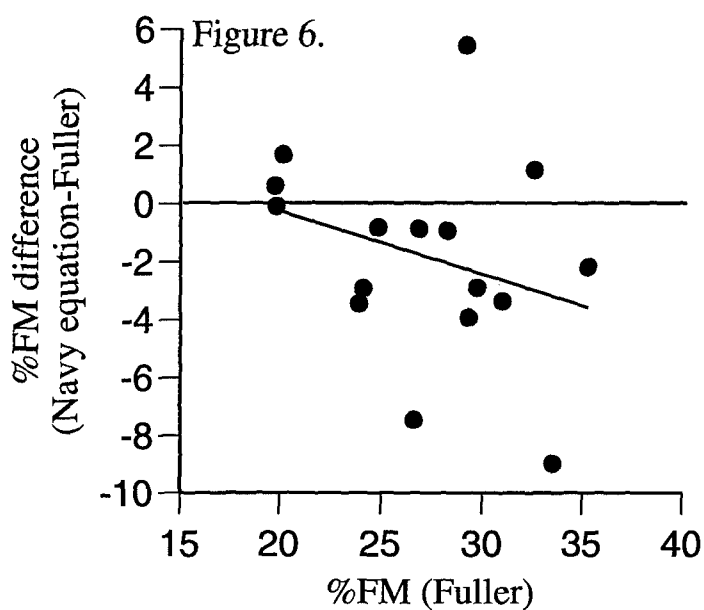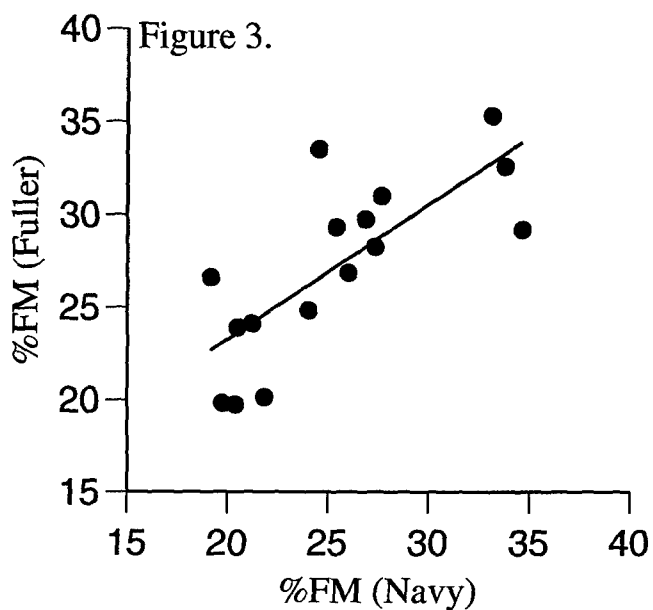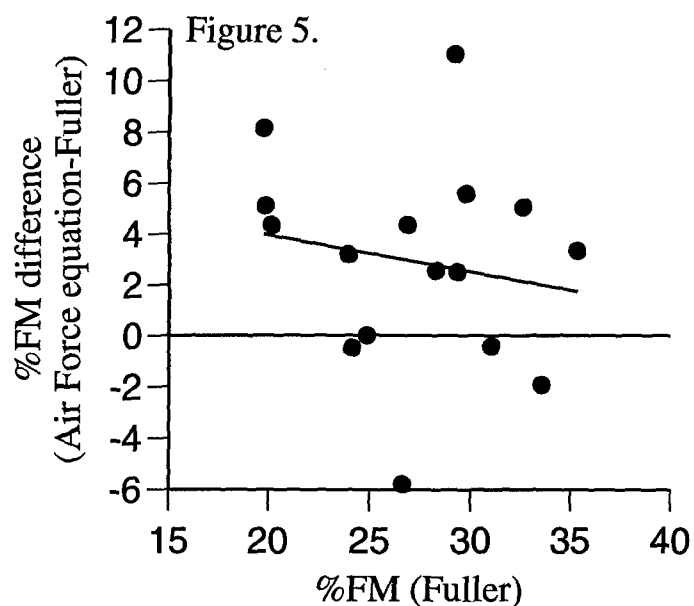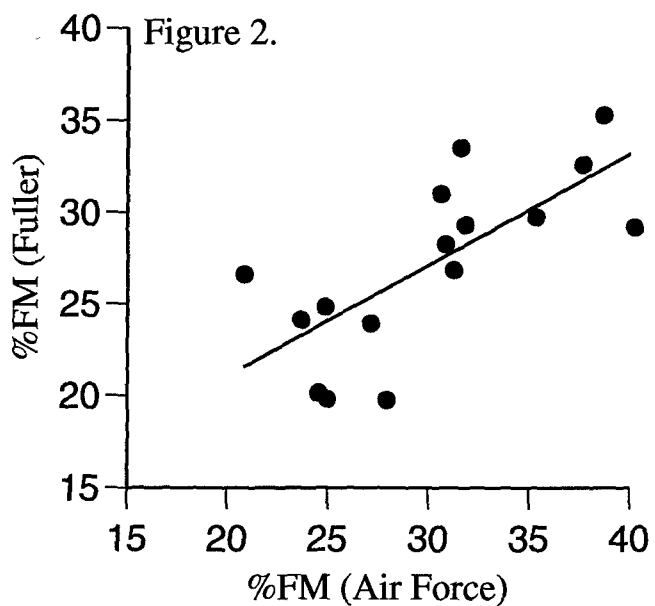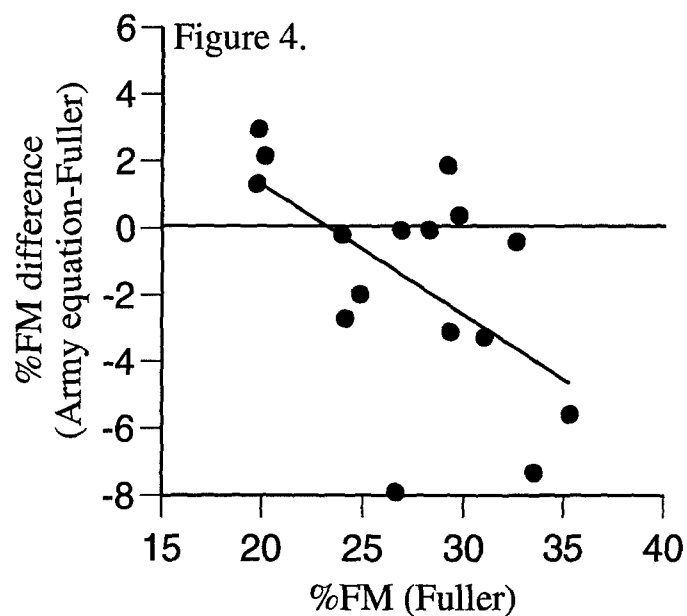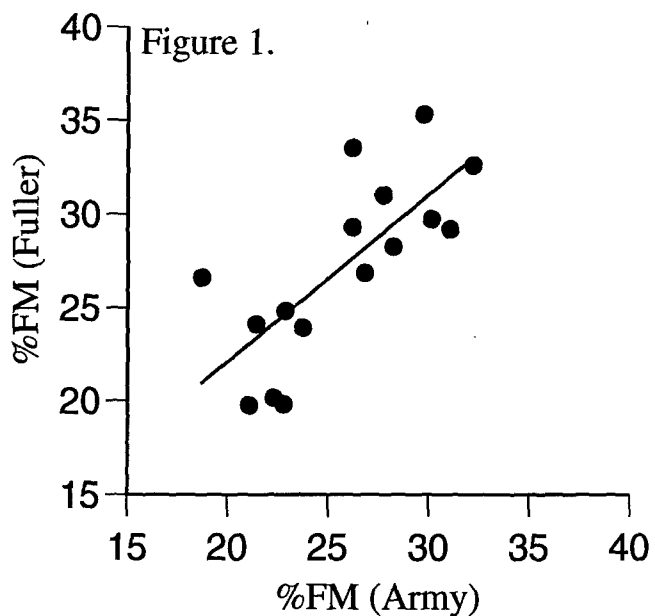
Fat-Free Mass Compartment

In terms of work capacity and physical fitness, the fat-free mass compartment is the metabolically active part of the body. We will monitor changes in FFM during pregnancy and the postpartum period. We will test whether physical activity can maintain a higher level of physical fitness throughout pregnancy and prevent an undesirable loss of muscle mass associated with postpartum weight loss. We will also be able to relate changes in FFM to any changes in strength.

Based on the principle that the K/N ratio for muscle is higher than that of nonmuscle tissues (3.03 vs 1.33 meq/g), TBK and TBN will be used to estimate the relative amounts of protein in muscle and nonmuscle components of the body and the mass of each component prior to conception and postpartum.

Prior to conception, bone mineral density of all subjects was within the normal range (0.98 to 1.31). Changes in bone mineral density will be determined in the postpartum period in these reproductive women.

Table 12. Fat-free mass (FFM) compartment determined by total body potassium, DEXA, and prompt-gamma activation				
		Pre-pregnancy n=19	8 wk pregnancy n=6	22 wk pregnancy n=4
Total body potassium (TBK)				
TBK	g	106.7 ± 15.8*	99.86 ± 6.43	99.70 ± 10.88
^{40}K lean body mass	kg	45.35 ± 6.70	42.44 ± 2.73	42.35 ± 4.62
^{40}K body cell mass	kg	22.74 ± 3.37	21.29 ± 1.38	21.25 ± 2.31
Dual energy x-ray absorptiometry (DEXA)			**	**
Bone mineral content (BMC)	kg	2.36 ± 0.35		
Bone mineral density (BMD)	g/cm^2	1.17 ± 0.08		
Lean body mass	kg	41.95 ± 5.79		
Prompt-gamma activation analysis (PGA)			**	**
Total body nitrogen	g	1476 ± 189		
Muscle mass	kg	15.0 ± 4.6		
Nonmuscle mass	kg	28.4 ± 5.2		

*Mean ±SD
** Measurement not performed during pregnancy

Energy Expenditure and Substrate Utilization by Room Respiration Calorimetry

Preconceptional baseline levels of energy expenditure and substrate utilization are summarized in Tables 13 and 14. By study design, the mean 24-h TEE and heart rates are representative of sedentary conditions. These data will be used to evaluate changes in energy metabolism and their impact on energy requirements throughout the reproductive cycle in women with low and normal BMIs. The data will be analyzed for evidence of an effect of iron deficiency on basal energy expenditure and submaximal work performance.

28

Table 13. Respiration room calorimetry		Pre-pregnancy n=19	8 wk pregnancy n=6	22 wk pregnancy n=4
Total energy expenditure (TEE)				
Heart rate	bpm	64 ± 8*	66 ± 11	74 ± 6
Activity	counts	99 ± 20	96 ± 15	93 ± 3
VO_2	lpm	0.26 ± 0.03	0.26 ± 0.01	0.26 ± 0.02
VCO_2	lpm	0.22 ± 0.02	0.23 ± 0.01	0.23 ± 0.01
RQ		0.87 ± 0.02	0.89 ± 0.01	0.90 ± 0.02
TEE	kcal/m	1.25 ± 0.14	1.27 ± 0.06	1.29 ± 0.09
TEE	kcal/d	1801 ± 194	1822 ± 84	1851 ± 129
TEE	$kcal \cdot kg^{-1} \cdot d^{-1}$	29.67 ± 2.14	31.75 ± 2.39	30.32 ± 1.
Basal metabolic rate (BMR)				
Heart rate	bpm	59 ± 8	64 ± 13	70 ± 6
Activity	counts	4 ± 4	5 ± 5	6 ± 5
VO_2	lpm	0.19 ± 0.02	0.20 ± 0.01	0.20 ± 0.02
VCO_2	lpm	0.15 ± 0.02	0.16 ± 0.01	0.17 ± 0.01
RQ		0.81 ± 0.04	0.81 ± 0.05	0.85 ± 0.03
BMR	kcal/m	0.93 ± 0.09	0.97 ± 0.06	0.99 ± 0.09
BMR	kcal/d	1333 ± 125	1399 ± 81	1420 ± 126
BMR	$kcal \cdot kg^{-1} \cdot d^{-1}$	21.99 ± 1.73	24.35 ± 1.48	23.23 ± 1.17
TEE/BMR		1.35 ± 0.06	1.30 ± 0.05	1.31 ± 0.03
Sleeping metabolic rate (SMR)				
Heart rate	bpm	57 ± 7	59 ± 9	67 ± 5
Activity	counts	7 ± 2	11 ± 2	9 ± 1
VO_2	lpm	0.19 ± 0.02	0.19 ± 0.01	0.20 ± 0.01
VCO_2	lpm	0.16 ± 0.01	0.17 ± 0.01	0.18 ± 0.01
RQ		0.83 ± 0.02	0.85 ± 0.03	0.88 ± 0.01
SMR	kcal/m	0.91 ± 0.09	0.95 ± 0.04	0.99 ± 0.06
SMR	$kcal \cdot kg^{-1} \cdot d^{-1}$	21.73 ± 1.82	23.84 ± 1.62	23.46 ± 1.12
Minimal metabolic rate (MMR)				
Heart rate	bpm	56 ± 8	57 ± 9	68 ± 7
Activity	counts	2 ± 3	3 ± 2	2 ± 2
VO_2	lpm	0.17 ± 0.02	0.18 ± 0.01	0.19 ± 0.00
VCO_2	lpm	0.14 ± 0.02	0.15 ± 0.01	0.16 ± 0.01
RQ		0.83 ± 0.04	0.85 ± 0.03	0.84 ± 0.05
MMR	kcal/m	0.85 ± 0.09	0.87 ± 0.04	0.91 ± 0.03
MMR	$kcal \cdot kg^{-1} \cdot d^{-1}$	20.05 ± 1.46	21.86 ± 1.40	21.49 ± 0.8

*Mean ± SD

Table 14. Substrate utilization estimated from 24-h respiration calorimetry				
		Pre-pregnancy n=19	8 wk pregnancy n=6	22 wk pregnancy n=4
Energy intake (EI)	kcal/d	1726 ± 220*	1915 ± 332	2096 ± 308
Diet fat	% EI	31 ± 1	32 ± 2	32 ± 1
Diet carbohydrate	% EI	51 ± 2	50 ± 3	49 ± 1
Diet protein	% EI	20 ± 1	19 ± 1	20 ± 1
Energy balance	kcal/d	-25 ± 108	94 ± 291	245 ± 192
Urinary nitrogen	g/d	10.6 ± 2.0	11.0 ± 1.9	12.0 ± 2.2
Respiratory quotient (RQ)		0.87 ± 0.02	0.89 ± 0.01	0.90 ± 0.02
Protein utilization	g/d	66 ± 12	68 ± 12	75 ± 14
Carbohydrate utilization	g/d	205 ± 35	241 ± 26	283 ± 28
Fat utilization	g/d	65 ± 17	53 ± 10	34 ± 7
Protein utilization	% TEE	17 ± 3	18 ± 3	19 ± 2
Carbohydrate utilization	% TEE	48 ± 8	55 ± 4	64 ± 3
Fat utilization	% TEE	34 ± 7	27 ± 5	18 ± 4
Nonprotein VO_2	l/d	301 ± 36	307 ± 25	305 ± 22
Nonprotein VCO_2	l/d	263 ± 30	276 ± 22	284 ± 21
Nonprotein RQ		0.87 ± 0.03	0.90 ± 0.02	0.93 ± 0.01
Nonprotein EE	kcal/d	1470 ± 174	1511 ± 123	1511 ± 108
Carbohydrate utilization	%NPEE	58 ± 9	67 ± 6	78 ± 4
Fat utilization	%NPEE	41 ± 9	33 ± 6	22 ± 4

*Mean ± SD

30

Total Energy Expenditure by Doubly-Labeled Water Method

Free-living energy expenditure averaged 2536±368 kcal/d or 41±6 kcal·kg^{-1}·d^{-1} in these nonpregnant women. Mean activity energy expenditure (AEE=TEE-BMR-0.1TEE) of 939±307 kcal/d and the physical activity level (PAL=TEE/BMR) of 1.90±0.25 both indicated a high level of physical activity. Inspection of individual AEE or PAL values revealed moderate to high levels of physical activity. This is not surprising since our study design called for physically-active women participating in some form of exercise. Except for one case, these rates of daily energy expenditure would be classified as moderate (1.64) or heavy (1.82), according to FAO/WHO/UNU (4).

Measurements of TEE, AEE, and PAL will allow us to assess changes in activity during pregnancy and the postpartum period. In conjunction with the fitness and strength tests, we can assess whether pregnancy-induced changes in activity influence the ability to return to military duty.

Table 15. Total energy expenditure (TEE) by doubly-labeled water method		
	Pre-pregnancy n=19	22 wk pregnancy n=6
^{2}H dilution space (kg)	35.02 ± 5.04*	32.0 ± 3.85
^{18}O dilution space (kg)	33.93 ± 4.88	31.7 ± 4.26
^{2}H/^{18}O	1.04 ± 0.02	1.01 ± 0.01
^{2}H slope (k_H)	-0.113 ± 0.027	-0.124 ± 0.001
^{18}O slope (k_O)	-0.140 ± 0.029	-0.150 ± 0.008
rCO_2 (mol/d)	19.89 ± 2.89	19.53 ± 0.99
rO_2 (mol/d)	23.13 ± 3.36	22.71 ± 1.15
TEE (kcal/d)	2536.2 ± 368.4	2490.3 ± 126.5
TEE (kcal·kg^{-1}·d^{-1})	41.40 ± 5.51	41.32 ± 6.36

*Mean ± SD

Fitness and Strength

The measurement of VO$_2$max allows us to categorize these women in terms of pre-pregnancy fitness. The mean VO$_2$max was 36 ml·kg^{-1}·min^{-1}. Based on a mean age of 31.7 y, the mean fitness level of these women would be categorized as "good" (34-44 ml·kg^{-1}·min^{-1}), according to Katch & McArdle (65). A breakdown into fitness categories reflects considerable individual variation in physical fitness: "fair" (n=4), "average" (n=8), "good" (n=4) and "high" (n=2). Maximal heart rates and the high RQ (1.20) demonstrate that a true maximal oxygen uptake was achieved by these women. The mean maximal workload was 183 watts, indicating a high level of work reached at exhaustion.

Oxygen consumption of steady-state cycle exercise at 50 watts was equal to ~39% of VO_2max. Submaximal exercise on the treadmill at 2.5mph elicited a response equivalent to ~30% of VO_2max. Submaximal exercise on the treadmill and cycle will provide us with two different modalities and different exercise costs (percent VO_2max) with which to examine changes in aerobic capacity before and after pregnancy. The workloads chosen are appropriate to test for differences in the ability of women to complete submaximal work prior to and after pregnancy.

From the one-repetition maximum strength testing, it appears that these women have fairly strong upper bodies. For example, the women can bench press about 64% of their body weight. For the lower body, the women seem to have fairly strong muscles to complete the leg extension. The values for the modular leg press, which would be expected to be greater than the leg extension, appear low. This may be due to the type of equipment used for the leg press. As with the measure of fitness, there seems to be a great deal of variability in the group for strength, possibly due to the heterogeneity of the body composition and participation in regular strength training.

The military contends that all individuals need to maintain a certain level of physical fitness to preserve the combat readiness of the services. These measurements of physical fitness and strength will be used to assess alterations due to pregnancy. The fitness and strength tests will allow us to make inferences as to whether women in the military can accomplish their work tasks when required to return to duty after pregnancy.

Table 16. Physical fitness and strength		Pre-pregnancy n=19	8 wk pregnancy n=6	22 wk pregnancy n=4
Steady state exercise on stationary cycle ergometer				
Workload	watts	50 ± 0*		
Heart rate	bpm	110 ± 13		
VO_2	lpm	0.91 ± 0.10		
VO_2	$ml\cdot kg^{-1}\cdot m^{-1}$	15.01 ± 1.72		
Respiratory quotient (RQ)		0.91 ± 0.06		
Ventilation rate	lpm	24.4 ± 3.6		
Respiration rate	breaths/m	20 ± 5		
Percent VO_2max	%	39.05 ± 8.48		
Maximal exercise on stationary cycle ergometer				
Workload	watts	183 ± 26		
Heart rate	bpm	174 ± 10		
VO_2	lpm	2.16 ± 0.32		
VO_2	$ml\cdot kg^{-1}\cdot m^{-1}$	36.13 ± 7.62		
RQ		1.20 ± 0.06		
Ventilation rate	lpm	79.4 ± 14.1		
Respiration rate	breaths/m	39 ± 7		
Strength testing: 1-Repetition Maximum				
Cybex modular leg press	lb	87 ± 40		
Cybex leg extension	lb	88 ± 24		
Smith bench press	lb	87 ± 21		
Cybex latissimus pull-down	lb	68 ± 13		
Submaximal exercise on treadmill @ 2.5 mph				
Heart rate	bpm	90 ± 12	94 ± 22	101 ± 13
VO_2	lpm	0.67 ± 0.14	0.66 ± 0.13	0.65 ± 0.09
VCO_2	lpm	0.59 ± 0.13	0.60 ± 0.12	0.59 ± 0.09
RQ		0.89 ± 0.03	0.92 ± 0.05	0.90 ± 0.01
Energy expenditure	kcal/m	3.29 ± 0.70	3.27 ± 0.63	3.23 ± 0.46

*Mean ± SD

33

8. CONCLUSIONS

This study addresses the impact of pregnancy-induced changes in body composition and physical fitness on postpartum return to duty readiness. In this first annual report, preliminary data are presented on the subjects enrolled thus far. Prior to conception, the subjects represent healthy, moderately-active women. Based on military standards, all subjects would be eligible for the Armed Services. The weight, body fat, bone density and iron status of these women are within normal limits. Energy expenditure measurements indicate that these women are physically active. VO_2max and strength tests confirm that the women are fit and fairly strong. With our full data-set of preconceptional and postpartum women, we will be able to evaluate the accuracy of the military fat mass prediction equations and their validity in postpartum women. Further, the effect of gestational weight gain, fat accretion and deconditioning on the ability to return to weight, body fat and fitness standards in the 6 months following delivery will be assessed. We will be able to test our hypothesis that moderate levels of physical activity will maintain physical fitness and limit excess fat deposition during pregnancy and facilitate fat mobilization and conserve fat-free mass during postpartum weight loss.

9. REFERENCES

1. U.S. Department of Army. 1986. Army Regulation 600-9, "The Army Weight Control Program." September 1, Washington D.C.

2. Vogel JA, Kirkpatrick JW, Fitzgerald PI, Hodgdon JA, Harman EA. Derivation of anthropometry based body fat equations for the Army's weight control program. 1988. Technical Report No. T17-88, U.S. Army Research Institute of Environmental Medicine, Natick, MA.

3. Hodgdon JA, Beckett MB. Prediction of percent body fat for U.S. Navy women from body circumference and height. 1984. Report No. 84-29. Naval Health Research Center, San Diego, CA.

4. Wright HF, Wilmore JH. Estimation of relative body fat and lean body weight in a United States Marine Corps population. 1974. Aerospace Med 45: 301-6.

5. Brennan EH. Development of a binomial involving anthropometric measurements for predicting lean mass in young women. 1974. M.S. thesis. Incarnate Word College, San Antonio, TX.

6. U.S. Department of Army. 1983. Army Regulation 40-501, Change 34, "Standards of Medical Fitness." December 1, Washington, D.C.

7. Institute of Medicine, Food and Nutrition Board, Committee on Military Nutrition Research. 1992. In: Mariott BM, Grumstrup-Scott J. (ed), Body composition and physical performance. National Academy Press.

8. Laurence MT. Enlistment height/weight standards and attrition from the military. Defense Manpower Data Center, Arlington, VA.

9. Institute of Medicine, Food and Nutrition Board, Committee on Nutritional Status During Pregnancy and Lactation. Nutrition during pregnancy. Part I. Weight gain. Part II. Nutrient supplements. 1990. Washington, DC: National Academy Press.

10. Naeye RL. Weight gain and the outcome of pregnancy. 1979. Am J Obstet Gynecol 135:3-9.

11. Taffel SM. Maternal weight gain and the outcome of pregnancy: US, 1980. 1986. Vital and Health Statistics, Series 21, No. 44. DHHS Publ. No. (PHS) 86-1922.

12. Langhoff-Roos J, Lindmark G, Gebre-Medhin M. Maternal fat stores and fat accretion during pregnancy in relation to infant birthweight. 1987. Brit J Obs Gyn 94:1170-7.

13. Lawrence M, McKillop FM, Durnin JVGA. Women who gain more fat during pregnancy may not have bigger babies: implications for recommended weight gain during pregnancy. 1991. Brit J Obs Gyn 98:254-9.

14. Hytten FE. Weight gain in pregnancy. 1991. In: Clinical physiology in obstetrics. Hytten FE, Chamberlain G, eds. Blackwell Scientific Publications. Oxford.

15. Hytten FE, Thomson AM, Taggert N. Total body water in normal pregnancy. 1966. J Obstet Gynaecol Br Commonw 73:553-61.

16. Fitch WL, King JC. Protein turnover and 3-methylhistidine excretion in non-pregnant, pregnant and gestational diabetic women. 1987. Hum Nutr Clin Nutr 41C:327-39.

17. Naismith DJ. Maternal nutrition and the outcome of pregnancy - a critical appraisal. 1980. Proc Nutr Soc 39:1-11.

18. Sohlström A, Wahlund L-O, Forsum E. Total body fat and its distribution during human reproduction as assessed by magnetic resonance imaging. 1993. In: Ellis K (ed), Human Body Composition pp 181-184.

19. Dewey KG, Heinig MJ, Nommsen LA. Maternal weight-loss patterns during prolonged lactation. 1993. Am J Clin Nutr 58:162-166.

20. Brewer MM, Bates MR, Vannoy LP. Postpartum changes in maternal weight and body fat depots in lactating vs non-lactating women. 1989. Am J Clin Nutr 49:259-265.

21. Taggart NR, Holliday RM, Billewics WZ, Hytten FE, Thomson AM. Changes in skinfolds during pregnancy. 1967. Br J Nutr 21:439-51.

22. Goldberg GR, Prentice AM, Coward WA, Davies HL, Murgatroyd PR, Wensing C, Black AE, Harding M, Sawyer M. Longitudinal assessment of energy expenditure in pregnancy by the doubly labelled water method. 1993. Am J Clin Nutr 57:494-505.

23. van Raaij JMA, Peek MEM, Vermaat-Miedema SH, Schonk CM, Hautvast JGAJ. New equations for estimating body fat mass in pregnancy from body density or total body water. 1988. Am J Clin Nutr 48:24-9.

24. Pipe NGJ, Smith T, Halliday D, Edmonds CJ, Williams C, Coltart TM. Changes in fat, fat-free mass and body water in human normal pregnancy. 1979. Br J Obstet Gynaecol 86:929-40.

25. Forsum E, Sadurskis A, Wager J. Resting metabolic rate and body composition of healthy Swedish women during pregnancy. 1988. Am J Clin Nutr 47:942-47.

26. King JC, Butte NF, Bronstein MN, Kopp LE, Lindquist SA. Energy metabolism during pregnancy: influence of maternal energy status. 1994. Am J Clin Nutr 59:439S-45S.

27. Johnson EM. Weight changes during pregnancy and the postpartum period. 1991. Progress in Food and Nutr Sci 15:117-57.

28. Keppel K, Taffel S. Pregnancy-related weight gain and retention: implications of the 1990 Institute of Medicine Guidelines. 1993. Am J Publ Health 83:1100-3.

29. Butte NF, Garza C, Stuff JE, Smith EO, Nichols BL. Effect of maternal diet and body composition on lactational performance. 1984. Am J Clin Nutr 39:296-306.

30. Manning-Dalton C, Allen LH. The effects of lactation on energy and protein consumption, postpartum weight change and body composition of well nourished North American women. 1983. Nutr Res 3:293-308.

31. Strode MA, Dewey KG, Lonnerdal B. Effect of short-term maternal caloric restriction on lactation performance of well-nourished mothers. 1986. Acta Paediatr Scand 75:222-9.

32. Forbes GB. Human Body Composition. 1987. Springer-Verlag, New York.

33. Ballor DL, Poehlman. Exercise-training enhances fat-free mass preservation during diet-induced weight loss: a meta-analytical finding. 1994. International J Obesity 18:35-40.

34. McMurray RG, Mottola MF, Wolfe LA, Artal R, Millar L, Pivarnik JM. Recent advances in understanding maternal and fetal responses to exercise. 1993. Med Sci Sports Exerc 25:1305-21.

35. Sady SP, Carpenter MW, Sady MA, Haydon B, Hoegsberg B, Cullinane EM, Thompson PD, Coustan DR. Prediction of $Vo_{2\,max}$ during cycle exercise in pregnant women. 1988. J Appl Physiol 65:657-61.

36. Lotgering FK, van Doorn MB, Struijk PC, Pool J, Wallenburg HCS. Maximal aerobic exercise in pregnant women: heart rate, O_2 consumption, CO_2 production, and ventilation. 1991. J Appl Physiol 70:1016-23.

37. South-Paul JE, Rajagopal KR, Tenholder MF. Exercise responses prior to pregnancy and in the postpartum state. 1992. Med Sci Sports Exerc 24:410-4.

38. American College of Obstetricians and Gynecologists. Exercise during pregnancy and the postnatal period. 1985. ACOG Home Exercise Programs. Washington, DC: ACOG.

39. Viteri FE. Influence of iron nutrition on work capacity and performance. 1989. In: Dietary Iron: Birth to Two Years, ed LF Filer, Jr. Raven Press, Ltd., New York, 141-60.

40. Lukaski HC, Ball CB, Siders WA. Altered metabolic response of iron-deficient women during graded, maximal exercise. 1991. Eur J Appl Physiol 63:140-5.

41. FAO/WHO/UNU Expert Consultation. Energy and protein requirements. 1985. Technical Report Series 724, WHO, Geneva.

42. National Research Council. Recommended dietary allowances. 10th ed. Washington, DC: National Academy Press, 1989.

43. Committee on Medical Aspects of Food Policy. Dietary reference values for food energy and nutrients for the United Kingdom. 1991. Dept Hlth Rep Hlth Soc Subj 41. London: HMSO.

44. Durnin JVGA, McKillop FM, Grant S, Fitzgerald G. 1987. Energy requirements of pregnancy in Scotland. Lancet ii:897-900.

45. van Raaij JMA, Schonk CM, Vermaat-Miedema SH, Peek MEM, Hautvast JGAJ. Body fat mass and basal metabolic rate in Dutch women before, during, and after pregnancy: a reappraisal of energy cost of pregnancy. 1989. Am J Clin Nutr 49:765-72.

46. Prentice AM, Goldberg GR, Davies HL, Murgatroyd PR, Scott W. Energy-sparing adaptations in human pregnancy assessed by whole-body calorimetry. 1989. Br J Nutr 62:5-22.

47. de Groot LCPGM, Boekholt HA, Spaaij CJK, van Raaij JMA, Drijvers JJMM, van der Heijden LJM, van der Heide D, Hautvast JGAJ. Energy balances of healthy Dutch women

before and during pregnancy: limited scope for metabolic adaptations in pregnancy. 1994. Am J Clin Nutr 59:827-32.

48. Forsum E, Kabir N, Sadurskis A, Westerterp K. Total energy expenditure of healthy Swedish women during pregnancy and lactation. 1992. Am J Clin Nutr 56:334-42.

49. King N, Fridlund KE, Askew EW. Nutrition issues of military women. 1993. J Amer Coll Nutr 12:344-8.

50. Friedl KE, Marchitelli LJ, Sherman DE, Tulley R. Nutritional Assessment of Cadets at the US Military Academy: Part 1. Anthropometric and Biomedical Measures." Natick MA: US Army Research Institute of Environmental Medicine. 1990. USARIEM Technical Report T4-91.

51. U.S. Department of the Army, Navy and the Air Force. Army Regulation 40-25/Naval Command Medical Instruction 10110.1/Air Force Regulation 160-95. Nutrient Allowances, Standards, and Education. May 15, 1985, Washington, DC.

52. Akers R, Buskirk ER. An underwater weighing system utilizing "force cube" transducers. 1969. J Appl Physiol 26:649-52.

53. Wilmore JH, Vodak PA, Parr RB, Girandola RN, Billing JE. Further simplification of a method for determination of residual lung volume. 1980. Med Sci Sports Exercise 12:216-8.

54. Burkinshaw L, Hill GL, Morgan DB. Mass and composition of the fat-free tissues of patients with weight loss. 1979. Clin Sci 68:455-62.

55. Fuller NJ, Jebb SA, Laskey MA, Coward WA, Elia M. Four-compartment model for the assessment of body composition in humans: comparison with alternative methods, and evaluation of the density and hydration of fat-free mass. 1992. Clinical Science 82:687-93.

56. International Dietary Energy Consulting Group. The doubly-labeled water method for measuring energy expenditure: Technical Recommendations for use in humans. 1990. (Prentice AM, ed) International Atomic Energy Agency, Vienna, Austria.

57. Black AE, Prentice AM, Coward WA. Use of food quotients to predict respiratory quotients for the doubly labeled water method for measuring energy expenditure. 1986. Hum Nutr Clin Nutr 40C:381-91.

58. de V Weir JB. New methods for calculating metabolic rate with special reference to protein metabolism. 1949. J Physiol 109:1-9.

59. Moon JK, Vohra FA, Valerio-Jimenez OS, Butte NF. Closed-loop control of carbon dioxide concentration and pressure improves response of room respiration calorimetry. 1994. J Nutr [in press].

60. Livesey G, Elia M. Estimation of energy expenditure, net carbohydrate utilization, and net fat oxidation and synthesis by indirect calorimetry: evaluation of errors with special reference to the detailed composition of fuels. 1988. Amer J Clin Nutr 47:608-25.

61. Taylor HL, Jacobs DR, Schucker B, Knudsen J, Leon AS, Bebacker G. A questionnaire for the assessment of leisure time physical activities. 1978. J Chron Dis 31:741-55.

62. Shapiro S, Weinblatt E, Frank CW, Sagen V. The H.I.P. study of incidence and prognosis of coronary heart disease. 1965. J Chron Dis 18:527-58.

63. Dixon WJ (ed) 1983 BMDP, Biomedical computer programs. University of California Press, Berkeley, CA.

64. Minitab version 6.1 1988 Minitab, Inc., State College, PA.

65. Katch FI, McArdle WD (ed) 1983 Nutrition, weight control and exercise. Philadelphia, Lea & Febiger, p291.

10. **APPENDICES**: recruitment materials

Defense Women's Health Research Program

FIT FOR LIFE

A Study on Physical Fitness and Pregnancy

Are military weight and body fat retention standards appropriate for postpartum women? Do military women return to duty fitness by 6 months postpartum?

Military reserve and civilian women (including reservists' wives) are needed to participate in this important study at Baylor College of Medicine.

Volunteers will receive the following measurements before, during and/or after pregnancy at 2wk, 6wk and 6mo postpartum:

> Physical fitness assessments
> Body fat measurements
> Bone density analyses
> Strength testing
> Metabolic rate measurements
> Stipend to cover travel and expenses.

If you are planning to become pregnant or if you are already pregnant,

Call 798-7002 for more information.

Children's Nutrition Research Center

COLLEGE OF MEDICINE · BAYLOR · RESEARCH · EDUCATION · SERVICE

Texas Children's Hospital

UNITED STATES DEPARTMENT OF AGRICULTURE

United States	Extension	Children's Nutrition	1100 Bates
Department of	Service	Research Center	Houston, Texas
Agriculture		at Baylor College of Medicine	77030-2600

Dear Reservist:

We are pleased to announce a study funded under the Defense Women's Health Research Program to be conducted at the Children's Nutrition Research Center, Baylor College of Medicine in Houston. This study will address issues pertinent to the health and performance of all military women undergoing pregnancy. In this study changes in weight and body composition, strength and physical fitness, energy expenditure and physical activity will be measured through a complete reproductive cycle. Some of the questions we will be able to answer from this research are:
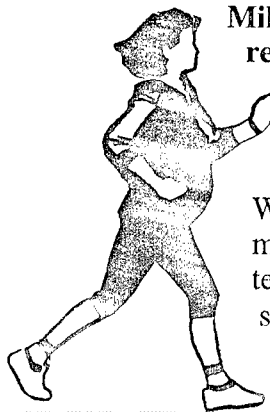
1. Is it physiologically reasonable for postpartum women to attain military weight and body fat retention standards by 6 months postpartum?
2. Do women return to duty fitness by 6 months postpartum?
3. Can moderate levels of physical activity maintain physical fitness throughout pregnancy?
4. Does a moderate level of physical activity limit excess fat gain during pregnancy?
5. How accurate are military equations to predict the body fat of individual women prior to pregnancy? Are the equations applicable for postpartum women?

Military reserve and civilian women, including reservists' wives, will be studied prior to becoming pregnant, during pregnancy, and afterwards until 6 months postpartum. Volunteers will receive their physical fitness assessments and body composition profiles. A stipend is provided to cover travel and personal expenses.

If you are pregnant or planning to become pregnant, please call us at 713-798-7002 or 798-7007 for more information about this important study.

Sincerely yours,

Nancy F. Butte, Ph.D.   Judy M. Hopkinson, Ph.D.   Carolyn Heinz, B.S.

(713) 798-7000 FAX: (713) 798-7098

REPLY TO
ATTENTION OF:

MCMR-RMI-S   (70-1y)   23 Aug 01

MEMORANDUM FOR Administrator, Defense Technical Information
Center (DTIC-OCA), 8725 John J. Kingman Road, Fort Belvoir,
VA 22060-6218

SUBJECT: Request Change in Distribution Statement

1. The U.S. Army Medical Research and Materiel Command has
reexamined the need for the limitation assigned to the technical
reports listed at enclosure. Request the limited distribution
statement for these reports be changed to "Approved for public
release; distribution unlimited." These reports should be
released to the National Technical Information Service.

2. Point of contact for this request is Ms. Judy Pawlus at
DSN 343-7322 or by e-mail at judy.pawlus@det.amedd.army.mil.

FOR THE COMMANDER:

Encl
                              PHYLIS M. RINEHART
                              Deputy Chief of Staff for
                                Information Management

Reports to be Downgraded to Unlimited Distribution

ADB241560	ADB253628	ADB249654	ADB263448
ADB251657	ADB257757	ADB264967	ADB245021
ADB263525	ADB264736	ADB247697	ADB264544
ADB222448	ADB255427	ADB263453	ADB254454
ADB234468	ADB264757	ADB243646	
ADB249596	ADB232924	ADB263428	
ADB263270	ADB232927	ADB240500	
ADB231841	ADB245382	ADB253090	
ADB239007	ADB258158	ADB265236	
ADB263737	ADB264506	ADB264610	
ADB239263	ADB243027	ADB251613	
ADB251995	ADB233334	ADB237451	
ADB233106	ADB242926	ADB249671	
ADB262619	ADB262637	ADB262475	
ADB233111	ADB251649	ADB264579	
ADB240497	ADB264549	ADB244768	
ADB257618	ADB248354	ADB258553	
ADB240496	ADB258768	ADB244278	
ADB233747	ADB247842	ADB257305	
ADB240160	ADB264611	ADB245442	
ADB258646	ADB244931	ADB256780	
ADB264626	ADB263444	ADB264797	